April 2021

Wildfire Report Series

Analysis of NFIRS Incidents in the Wildland Urban Interface

An Analysis of California NFIRS Data, 2009-2011

Summary

The wildland urban interface (WUI) is the area where housing and natural vegetation meet or intermingle. In the coterminous United States, between 1990 and 2010, the size of the WUI increased by 33% to 770,000 km^2 (190.3 million acres), and the number of homes in the WUI increased by 41% to 43.4 million (Radeloff et al., 2018). WUI areas may be the subject of increased attention due to the challenges posed by wildfires and because of recent increases in the number of structures destroyed, area burned and estimated damages annually by wildland fire.

Using National Fire Incident Reporting System (NFIRS) data, this paper examines the fire incidents in WUI areas in California in terms of travel time, loss measures and fire cause for the years 2009 to 2011 and compares those incidents to those outside WUI areas. California was chosen as the methodology test set as it experiences high levels of both wildfires and fires in the WUI, especially in recent years. Additionally, this paper presents a novel method for identifying incidents that occur in the WUI that has subsequently been adopted by the National Fire Data Center (NFDC): NFIRS data was geocoded and combined with existing U.S. Forest Service (USFS) WUI shapefiles to identify incidents that occurred in the WUI. This dataset creates a substantial new opportunity for linking local fire department incident responses and wildland fires.

The goals of the study were twofold: first, to develop a method to identify fires in the WUI, and second, once identified, to use NFIRS fire data to identify substantive differences, if any, between WUI and non-WUI areas to better understand how the risk from fire in the WUI may be mitigated. It is important to note that the WUI is a **geographic** area; a fire in the WUI can be any type of fire and not necessarily related to a wildfire or wildland fire. The analysis examines all types of fire incidents, including, but not limited to, wildland fires. Some of the conclusions drawn about fires in WUI areas may shape recommendations for how to mitigate the risk from fire in the WUI.

NFIRS-reported losses in the California WUI are substantial. California averages almost $154.6 million per year in building and structure losses in WUI areas. Mobile structure fires, such as mobile homes, in the WUI incur an additional $3 million per year in property damage; vehicle fire incidents in WUI areas add $19.4 million per year.

Analysis showed:

- Overall, travel times are higher in WUI areas than in urban areas. Median travel times are 20% to 40% higher depending on the incident type, and mean travel times are 24% to 53% longer.
- Increased travel times may have an impact on the losses in WUI areas, which are generally higher on a per-incident basis than in urban areas.
  - Imputed dollar loss per incident is 12% higher in WUI areas than urban areas for building and other structure fires (excluding contained fires), 9% higher for mobile structure fires, and 15% higher for vehicle fires.

FEMA | U.S. Fire Administration
Working for a fire-safe America

National Fire Data Center
16825 S. Seton Ave.
Emmitsburg, MD 21727
usfa.fema.gov

- Casualty rates for both firefighters and civilians appear to be higher in WUI areas than in urban areas. For building and other structure fires, firefighter injury rates are 14% higher in WUI areas than in urban areas. For the same fires, civilian death rates are 20% higher. While not as pronounced, casualty rates for mobile structure fires are also higher in WUI areas than in urban areas.

- Fire cause in WUI areas is more likely to be heating, cooking, appliances and open flame than in urban areas for building/non-building structures and mobile structures. Interestingly, among fires confined to their noncombustible container, heating is more likely to be the cause of fire in WUI areas than in either urban or rural areas. While more analysis is needed, this may suggest that heating fires in WUI areas are more likely to breach their noncombustible container while awaiting a fire department response.

- Although the data examined did not include a large number of exposure fires (fires caused by another fire), an exposure fire in the WUI area is twice as likely to have been sparked by a vegetation fire than in urban areas. Exposure fires sparked by vegetation fires are also twice as common in rural areas as urban areas.

National Fire Incident Reporting System incidents

NFIRS represents the world's largest national annual database of fire department incident information. Each year, approximately 24,000 fire departments from all 50 states, the District of Columbia, many Native American tribal authorities and the Department of Defense voluntarily report data on over 1 million fires and over 28 million other fire department-responded incidents such as hazardous material incidents or smoke scares.[1] NFIRS is not a census of all fire department-responded incidents, and it is not based on a statistically derived sample. Among other issues that prevent NFIRS from being a complete source for fire department incident data are reporting deadlines, data access and budgetary considerations.

For fire incidents, as with other NFIRS fire department-responded incidents, NFIRS raw totals do not reflect the whole of the U.S. fire problem; NFIRS contains incident data derived from voluntary reporting of fire incidents in the U.S. With the wealth of fire incident data contained in NFIRS, however, the U.S. Fire Administration (USFA) believes it is possible to harness NFIRS data for analyses of WUI-related fire incidents.

National Fire Incident Reporting System

The Federal Fire Prevention and Control Act of 1974 (P.L. 93-498) authorizes the USFA's NFDC to gather and analyze information on the magnitude of the nation's fire problem as well as its detailed characteristics and trends. The Act further authorizes the USFA to develop uniform data reporting methods and to encourage and assist state agencies in developing and reporting data. In order to carry out the intentions of the Act, the NFDC established NFIRS.

About the National Fire Incident Reporting System

NFIRS has 2 objectives: to help state and local governments develop fire reporting and analysis capability for their own use, and to obtain data that can be used to more accurately assess and subsequently combat the fire problem at a national level. To meet these objectives, the USFA has developed NFIRS data collection standards. This NFIRS package, maintained by USFA, includes forms, a coding structure for data processing purposes, a standard system specification, manuals, computer software and procedures, and documentation for using the system.

Generally, NFIRS collects fire incident data from state fire data systems. The state systems, in turn, collect data from their individual fire departments. State participation in NFIRS is voluntary and the guidelines for departmental participation within each state are determined by the state fire marshal's office or the equivalent agency. These guidelines can vary significantly from state to state. In most states, reporting by local departments is not mandatory; the departments that report are willing to participate and can afford the additional commitment necessary to collect the data.

Participating local fire departments fill out the incident reports as emergency responses occur. They forward the completed incidents via paper forms or digital transactions to their state reporting authority and to the USFA where the data is validated and consolidated into a single computerized database.

[1]National Fire Incident Reporting System (NFIRS) data from the Department of Defense is not released in the NFIRS Public Data Release.

The database is used to answer questions about the nature and causes of injuries, deaths and property losses resulting from fires. This information is disseminated through a variety of means to the public as well as to government and private organizations.

Representativeness of National Fire Incident Reporting System data

The percentage of fire departments participating in NFIRS varies from state to state, with some states not participating at all in some years. Even in this case, individual fire departments are currently able to submit incident data directly to the USFA. Thus, all fire departments in the country can participate, regardless of whether the state in which they are located participates. As the USFA has determined in past studies for the Office of Management and Budget (Federal Emergency Management Agency, 2011), the distribution of participants is reasonably representative of the entire nation, even though it is not a scientifically selected sample. The data set is so large and reasonably distributed geographically and by size of community that fire data analysts use the data to analyze the U.S. fire problem on a national level.

Most of the NFIRS data exhibit stability from one year to another without radical changes. Results based on the full data set are generally similar to those based on part of the data, another indication of data reliability (U.S. Fire Administration [USFA], National Fire Data Center [NFDC], 2014).

The wildland urban interface

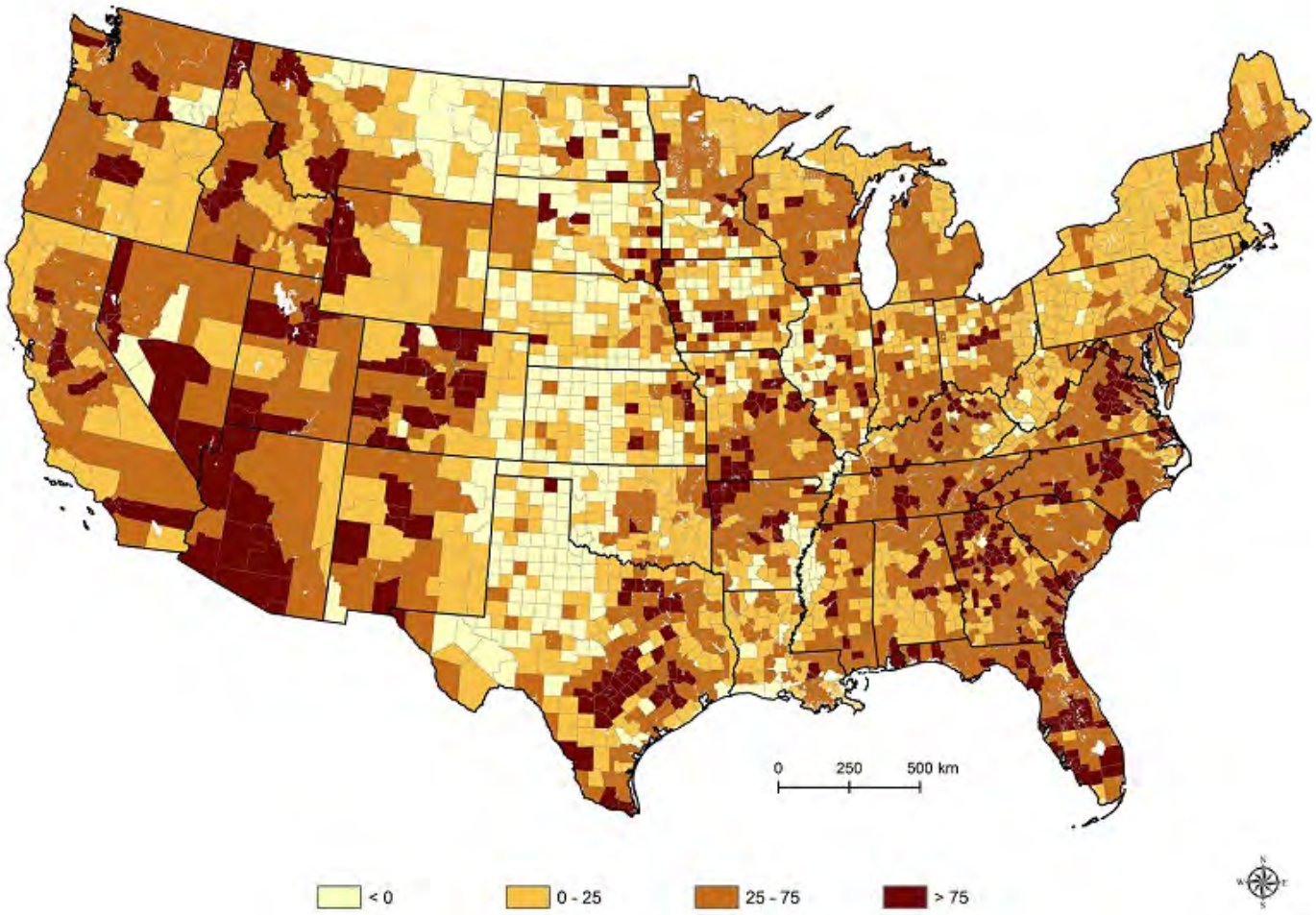
The WUI has received considerable attention because of recent increases in the number of deaths, structures destroyed, area burned and estimated costs by wildland fire as reported by the National Interagency Fire Center (National Interagency Fire Center [NIFC], 2019; NIFC, 2018). There have been a number of high-profile and costly wildland fires in recent years, including the 2019 Walker and Kincade fires in California that had a total estimated cost of $112.7 million (NIFC, 2019) and the 2018 Mendocino Complex, Carr, Camp, Woolsey, Ferguson, County and Delta fires in California that had a total estimated cost of $820.6 million (NIFC, 2018).

These wildfires are frequently affecting areas beyond the traditional wildlands as residential growth has expanded into these areas. This area, the WUI, creates new challenges as the close proximity of houses and wildland vegetation increases fire risk to people, structures and firefighters (Calkin et al., 2014). Fires in the WUI are more difficult to fight (Radeloff et al., 2018), which may result in increased property loss.

The problem is expanding quickly. Using U.S. Census data, National Land Cover Data and WUI definitions as stated in the Federal Register, researchers determined that the WUI has grown over the last several decades (Figure 1). From 1990 to 2010, the WUI grew from 30.8 million to 43 million homes and increased from 143.6 million acres to 190.3 million acres (Radeloff et al., 2018).[2]

[2]Data converted from km^2 to acres.

Figure 1. Growth rate of homes in the WUI 1990-2010 by county (in percent)



Source: USFS, https://www.nrs.fs.fed.us/news/release/wui-increase.

NFIRS data offers a unique perspective in examining some of the specific challenges in addressing fire in the WUI because of its abundance of incident-level reporting. The data, however, comes with its own challenges as discussed in the section below, National Fire Incident Reporting System and wildland urban interface data challenges.

Terminology

One of the challenges in understanding and analyzing fire incident and WUI data is inconsistent or confusing terminology. In the fire community, there are no standardized definitions for the basic terms of wildfires, wildland fires, WUI fires and WUI areas. Each group or agency that works with wildland fires uses its own definitions, in large part based on the way it collects data and how the agency is involved in the wildfire arena. Various definitions exist, and a further exploration of this topic is included in the Appendix. Most definitions are qualitative and descriptive. While the data is taken from NFIRS data and USFA has its own definitions of WUI and WUI-related terms, the definition of WUI that is most suitable for geospatial analysis is based on housing and population density published by the U.S. Department of Agriculture and the U.S. Department of the Interior in the Federal Register (Urban Wildland Interface Communities Within the Vicinity of Federal Lands that Are at High Risk from Wildfire, 2001). It defines WUI as an area where housing density is greater than 1 home per 40 acres, either intermixed with or in proximity to wildland vegetation. It is the definition used in this report. With geospatial data, 2 additional terms are used: intermix and interface. Areas where houses and wildland vegetation intermingle are referred to as “intermix WUI”; areas where

houses abut wildland vegetation are referred to as "interface WUI" (Radeloff et al., 2005). For purposes of analysis, this paper does not address any differences between interface or intermix WUI. Both groups are combined into the overall WUI dataset.

The following additional definitions have been adopted for this paper: **Wildfires** are a fire type involving vegetative or natural fuels, and **wildland** is a low-density population area where any kind of incident could occur. Wildlands may overlap with rural low-density population areas. Wildfires, as defined here, can occur in any land use area.

National Fire Incident Reporting System and wildland urban interface data challenges

There are many challenges in analyzing NFIRS data in the WUI, including missing incidents, data quality, the use of the data element "Area Type" to identify WUI fires, and missing loss data. These and other issues are explored more thoroughly in the USFA's preliminary review of NFIRS wildfire data (USFA, NFDC, 2020).

Missing incidents. Many of the federal agencies and other groups that combat wildland fires do not report to NFIRS. For example, the USFS, one of the primary responders to wildland fires, does not report their data to NFIRS. This underreporting of wildland fires can be significant. Other federal nonreporting agencies include U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. National Park Service and U.S. Bureau of Indian Affairs.

Local jurisdictions may underreport as well. A 2017 study of satellite-detected fires within areas of local jurisdiction in California found that only 32% of them could be identified in the NFIRS Public Data Release (PDR) file (Butry & Thomas, 2017). Further study by USFA of satellite-detected fires found that as many as 97% of them could not be matched to a fire (including prescribed fires and unauthorized burning) in NFIRS data (USFA, 2020).

Wildland data quality. The Wildland Fire Module, used to describe certain types of outside fires including wildfires more completely, is an optional module in NFIRS. It may be omitted if a department elects to record incident data via the Fire Module thereby leading to incomplete reporting of wildland-related fire data. In addition, for agencies that use the National Wildfire Coordinating Group Incident Status Summary Form (ICS-209) to report on wildfire incidents, there are data element differences between the NFIRS Wildland Module and the ICS-209, making a translation from one system to the other an imperfect fit.[3]

This incomplete reporting of wildland-related data is a primary reason that information in the Wildland Fire module is generally not reported in USFA annual statistics, and thus is not regularly reviewed for data quality. This results in occasional spectacularly incorrect entries in that module. For example, an incident from a department in Texas (TXWB701) on 12/9/2016 recorded 1,000,000,000 acres burned, and an incident from a department in Iowa (IA77008) on 7/6/2016 recorded 9,999,999 acres burned (USFA, 2016). These incidents are obvious incorrect entries.

Area type. The Wildland Fire Module has a field ("Area Type") that includes a selection of "Urban-wildland interface area" that could be used to help identify WUI incidents. But as the wildland module is typically only used to record wildfires, other incidents that occur in the WUI, such as structure and vehicle fires, will not be coded with this area type.

For the reasons above, this analysis will use only data that is present in the Basic Module (required data) in NFIRS and will ignore the data present in the Wildland Fire Module (optional data). The approach combines incidents in the Basic Module with their geolocation and existing WUI shapefiles to identify WUI incidents.

Dollar loss. There are further challenges in analyzing dollar loss data as reported to NFIRS. The NFIRS data on property and content losses are frequently underreported. Between 2009 and 2015, there were 6.4 million primary fire incidents[4], but no loss data was reported for 24% of these incidents. Additionally, the loss reported for an additional 47% of primary fire incidents was zero (USFA, 2017).

[3]The Incident Status Summary Form (ICS-209 WF) is intended to be used when an incident reaches a certain threshold where it becomes significant enough to merit special attention, require additional resource support needs, or cause media attention, increased public safety threat, etc. It is designed to provide a "snapshot in time" to effectively move incident decision support information where it is needed. It contains the most accurate and up-to-date information available at the time it is prepared. Multiple ICS-209 forms may be submitted during the course of an incident.

[4]NFIRS data distinguishes between "primary" and "aid" fire incidents. Primary incidents are those incidents where the reporting department has the primary or "first due" responsibility for the incident. "Aid" incidents are those where another department assists the primary department with additional manpower or equipment.

To address this underreporting, USFA has developed a method for estimating dollar loss where the data is missing or suspected incorrect. The method involves identifying cohorts of incidents where dollar loss is reported and using characteristics of those cohorts to apportion estimates for similar incidents where dollar loss is not reported (USFA, 2017).

To develop a more complete understanding of the WUI impact, both reported and estimated loss are used as part of this analysis.

Casualties. Other sources may report or record casualties, e.g., USFA's own annual firefighter fatality reports. The casualty data used in these analyses come exclusively from the fire incident data as reported to NFIRS.

Method

Wildland urban interface groups and classification

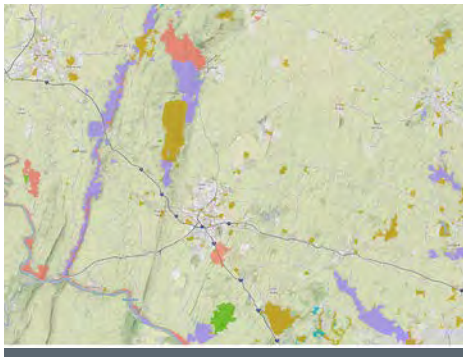
USFS shapefiles are the basis for the geographic description of the WUI. A shapefile is simply a file format for storing the "shape" or geometric location of geographic features. The USFS shapefiles not only store the shape (points, lines or polygons/areas) and location (latitude and longitude) of geographic characteristics, but they also classify each shape as belonging to an urban, WUI or rural area.

The USFS calculates WUI classifications by combining Census Block[5], Land Cover[6], and Protected Area datasets (Radeloff et al., 2017).[7] Samples of these datasets are shown in Figure 2.

Figure 2. USFS Shapefile input datasets

Tiger Census Block
(Census)

National Land Cover Database
(U.S. Geological Survey [USGS])

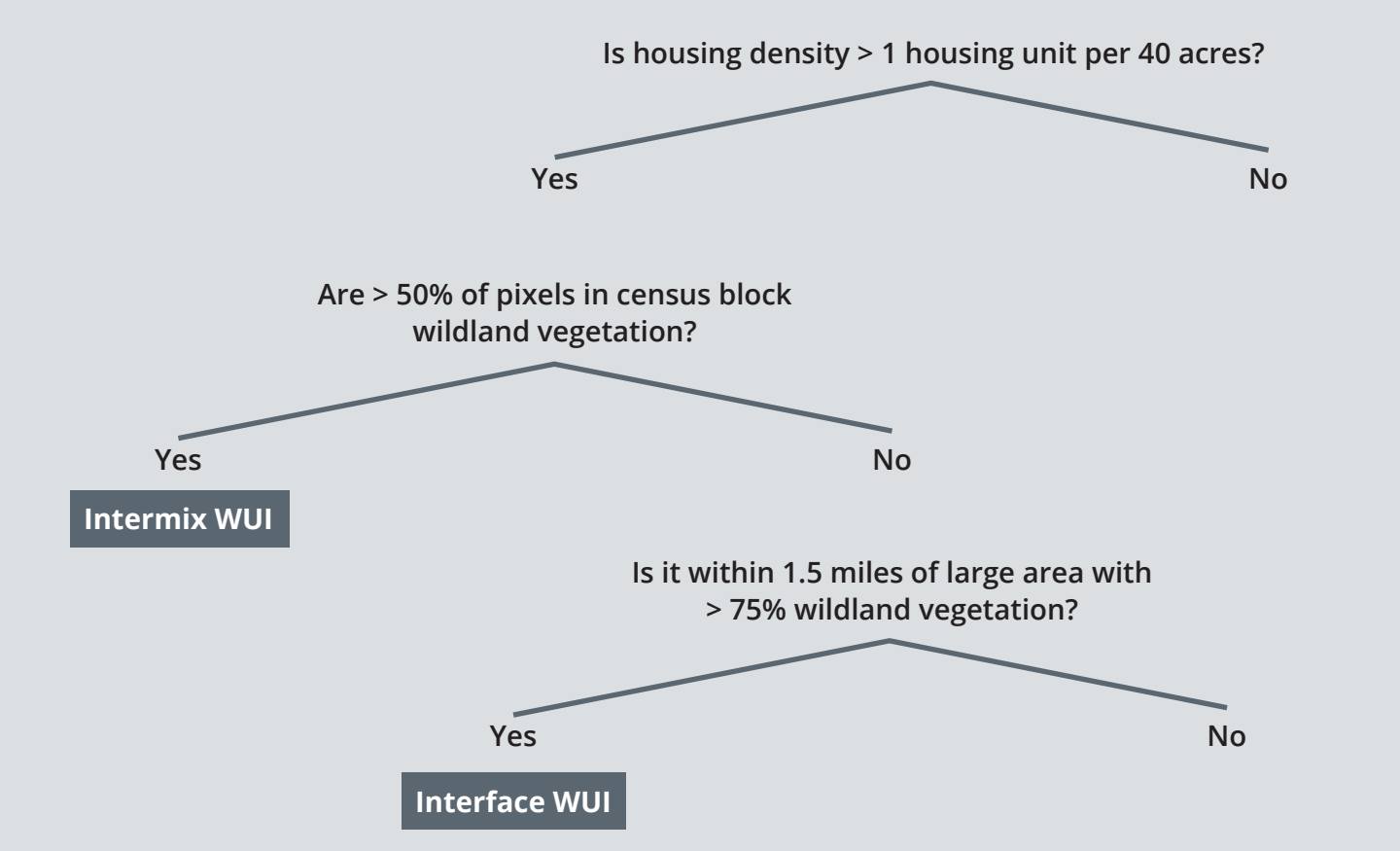


Protected Areas Database
(USGS, Radeloff et al.)

The specific definition of the WUI used in this analysis was developed from census-block level data to assess housing density (left dataset in Figure 2) and land use maps to determine the type and size of vegetation within each census block (middle dataset in Figure 2). If a census block has at least 1 home per 40 acres and over half of the census block's land use is wildland vegetation, the census block is labeled as "Intermix WUI." If a census block has at least 1 home per 40 acres and is within 1.5 miles of an area (over 1,235 acres) comprised of at least 75% wildland vegetation, it is labeled as "Interface WUI" (Stewart et al., 2007).

[5] https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
[6] https://www.usgs.gov/centers/eros/science/national-land-cover-database?qt-science_center_objects=0#qt-science_center_objects
[7] https://maps.usgs.gov/padus/

Figure 3. The WUI definition



Source: Stewart et al., 2007.

The USFS classifies census blocks into multiple categories (Radeloff et al., 2005). For this analysis, all intermix and interface classifications were combined as a WUI group; all high and medium density population, no vegetation classifications were combined as an Urban group; all low density population to uninhabited density no vegetation and all vegetation density classification were combined as a Rural group (Table 1).

Table 1. Grouping of WUI classifications

WUI classification	Area type
High Density Interface High Density Intermix Medium Density Interface Medium Density Intermix Low Density Interface Low Density Intermix	WUI
High Density No Vegetation Medium Density No Vegetation	Urban
Low Density No Vegetation Very Low-Density No Vegetation Very Low-Density Vegetation Uninhabited Vegetation Uninhabited No Vegetation	Rural

Approach to analyzing wildland urban interface and National Fire Incident Reporting System data

Combining wildland urban interface and National Fire Incident Reporting System data

USFS shapefiles are available for 1990, 2000 and 2010. The most recent shapefile, from 2010, was used for this paper. In this exploratory analysis, the state of California was selected due to the prevalence of wildfires and the ability to compare to other published studies. To be consistent with the shapefile data, all NFIRS fire incidents in California for the years 2009 to 2011 were selected for analysis.[8] This date range provides a sufficient population of data for further analysis. While all California fire incidents for 2009 to 2011 were included in the master dataset, subsets of the data were used where appropriate in the analyses.

Basic Module incident data in NFIRS includes address or location information but does not typically include geographic coordinates. This lack of location-specific coordinate data hampers the utility of NFIRS data in geospatial analyses. As a workaround, the GEOCODE Procedure in SAS 9.4 was used to identify the latitude and longitude for each incident.[9] The precision of geographical coordinates returned by the geocoder is limited by the quality of the input information and the sophistication of the geocoding algorithm.

The USFS shapefiles were joined with NFIRS geocoded data to identify the WUI classification for each incident using an R-based "point-in-polygon" calculation.[10,11] This approach to incorporating geographic data in NFIRS analyses has been subsequently employed by the USFA in its own analyses of NFIRS WUI data.

While NFIRS records location information for an incident, the incident locations are not always able to be geocoded accurately. Approximately 3% of NFIRS incidents did not contain sufficient information to be geocoded and were discarded. Some incidents that were geocoded were matched to USFS polygons with a WUI classification of "water," such as rivers or lakes, or were not matched to any USFS polygons. These NFIRS incidents were also removed from the analysis. While better address and location data or more accurate geocoding would increase the number of incidents available for analysis, the measures of central tendency of the overall distribution would not be expected to change. Table 2 shows the final incident totals for the analysis dataset.

Table 2. Summary of NFIRS WUI-geocoded incidents by year, California 2009-2011, all primary fire incidents

Year	Candidate fire incidents PDR	Fire incidents successfully placed in WUI polygon		Fire incidents in land-based polygons	
		Incidents	Percent	Incidents	Percent
2009	59,455	58,378	98.2	58,311	98.1
2010	62,469	60,063	96.1	59,979	96.0
2011	63,321	60,853	96.1	60,786	96.0
Total	185,245	179,294	96.8	179,076	96.7

National Fire Incident Reporting System data

NFIRS data distinguishes between "primary" and "aid" fire incidents. Primary incidents are those incidents where the reporting department has the primary or "first due" responsibility for the incident. "Aid" incidents, more properly called "aid given" incidents, are those where another department assists the primary department with additional manpower or equipment. This analysis only considers primary incidents to prevent the possible double counting of events.

[8]NFIRS classifies incidents according to type: fire, emergency medical service, hazardous materials and the like. Fires are defined as Incident Types 100-173. Prescribed and unauthorized burns (not in the Incident Type 100 Series) are not included.
[9]SAS is a statistical software suite used in the analysis of data that can mine, alter, manage and retrieve data from a variety of sources and perform statistical analysis on it. Originally developed at North Carolina State University, it is now managed by the SAS Institute.
[10]R is a programming language and software environment for statistical computing and graphics. The R language is widely used among statisticians and others for data exploration and analysis.
[11]In computational geometry, the point-in-polygon calculation determines whether a given point in the plane lies inside, outside or on the boundary of a polygon. It is an important calculation in applications that deal with processing geometrical data, such as in this analysis.

NFIRS data also distinguishes between larger fires in buildings and other structures and smaller building fires that are limited in extent, staying within pots, fireplaces or certain other noncombustible containers ("confined fires"). For structure fires, this analysis focuses primarily on the larger fires in buildings and other structures as these fires are where most property loss occurs.

Across all primary incidents grouped by major incident type groups, the most common incident type groups for the overall dataset are structure, rubbish, vehicle and vegetation fires. As well, structure fires are somewhat evenly divided between buildings and other structures and the smaller confined fires. For incidents in WUI areas, the most common incident type groups are similar although the order changes: structure, vegetation, rubbish and vehicle fires (Table 3). These 4 incident type groups account for an average of 90% of the fires in the dataset.

Table 3. NFIRS incidents by incident type group and area type, California 2009-2011, primary incidents, Incident Types 100-173

Incident type group	Urban		WUI		Rural		Total	
	Incidents	Percent	Incidents	Percent	Incidents	Percent	Incidents	Percent
11x - Structure	35,479	39.3	12,749	30.1	9,266	19.9	57,494	32.1
111, 112 Buildings and Other Structures	15,604	17.3	7,239	17.1	4,265	9.2	27,108	15.1
113-118 Confined Buildings	19,875	22.0	5,510	13.0	5,001	10.7	30,386	17.0
12x - Mobile Structure	495	0.5	513	1.2	413	0.9	1,421	0.8
13x - Vehicle	17,086	19.0	7,200	17.0	11,955	25.7	36,241	20.2
14x - Vegetation	9,532	10.6	9,948	23.5	11,503	24.7	30,983	17.3
15x - Rubbish	20,220	22.4	7,491	17.7	9,399	20.2	37,110	20.7
16x - Special Outside[12]	2,986	3.3	1,700	4.0	1,648	3.5	6,334	3.5
17x - Crop	401	0.4	215	0.5	528	1.1	1,144	0.6
100 - Other Fire	3,964	4.4	2,564	6.1	1,821	3.9	8,349	4.7
Total	90,163	100.0	42,380	100.0	46,533	100.0	179,076	100.0

Organization of the report

Structure fires, especially buildings and other structure fires, mobile structures, and vehicles are a primary source of loss (USFA, 2019a) and are of particular interest in the mitigation of fire incidents in the WUI. These groups are each analyzed in terms of their loss characteristics: number of incidents, incident travel time and losses (casualties and property loss). Overall, dollar loss is underreported in NFIRS and is not reported for over 70% of all primary fires reported to NFIRS (USFA, 2019b). During the 2009 to 2011 period, information on dollar loss was not reported in 57% of California primary fires. To supplement this underreporting, losses for incidents are imputed using historical data informed by incident type and location data (USFA, 2019b).[13] This imputed data was included in the analyses to analyze loss data more fully for incidents.

Other aspects of interest within the WUI areas are the cause of the fire and exposure fires. Cause is available in NFIRS only for structure fires and is examined separately for buildings and other structures and for confined building fires. The distributions of exposure fires — fires that are the result of another fire — are analyzed as well as their source fire.

Specific incident types for each incident type group are noted in the Appendix.

[12]The special outside fires category is outside fires with definable value such as outside trash compactors, outside heating, ventilating and air conditioning units, and irrigation pumps. It excludes crops and orchards which are under crop fires.
[13]Missing data imputation is a statistical method that replaces missing data points with valid, substituted values.

Results

Building and other structure fires

There are a sizable number of building and other structure fire incidents in NFIRS California data as seen in Table 4. Almost 27% of the building and other structure fire incidents in the data for 2009 to 2011 occurred in WUI areas. Note that these figures do not include the confined fire Incident Types 113-118.

Table 4. NFIRS incidents by area type, California 2009-2011, building and other structure fires, primary incidents, Incident Types 111-112

Area type	Building Fire (111)		Other Structure Fire (112)		Total	
	Incidents	Percent	Incidents	Percent	Incidents	Percent
Urban	14,712	58.0	892	51.7	15,604	57.6
WUI	6,750	26.6	489	28.3	7,239	26.7
Rural	3,919	15.4	346	20.0	4,265	15.7
Total	25,381	100.0	1,727	100.0	27,108	100.0

Travel time

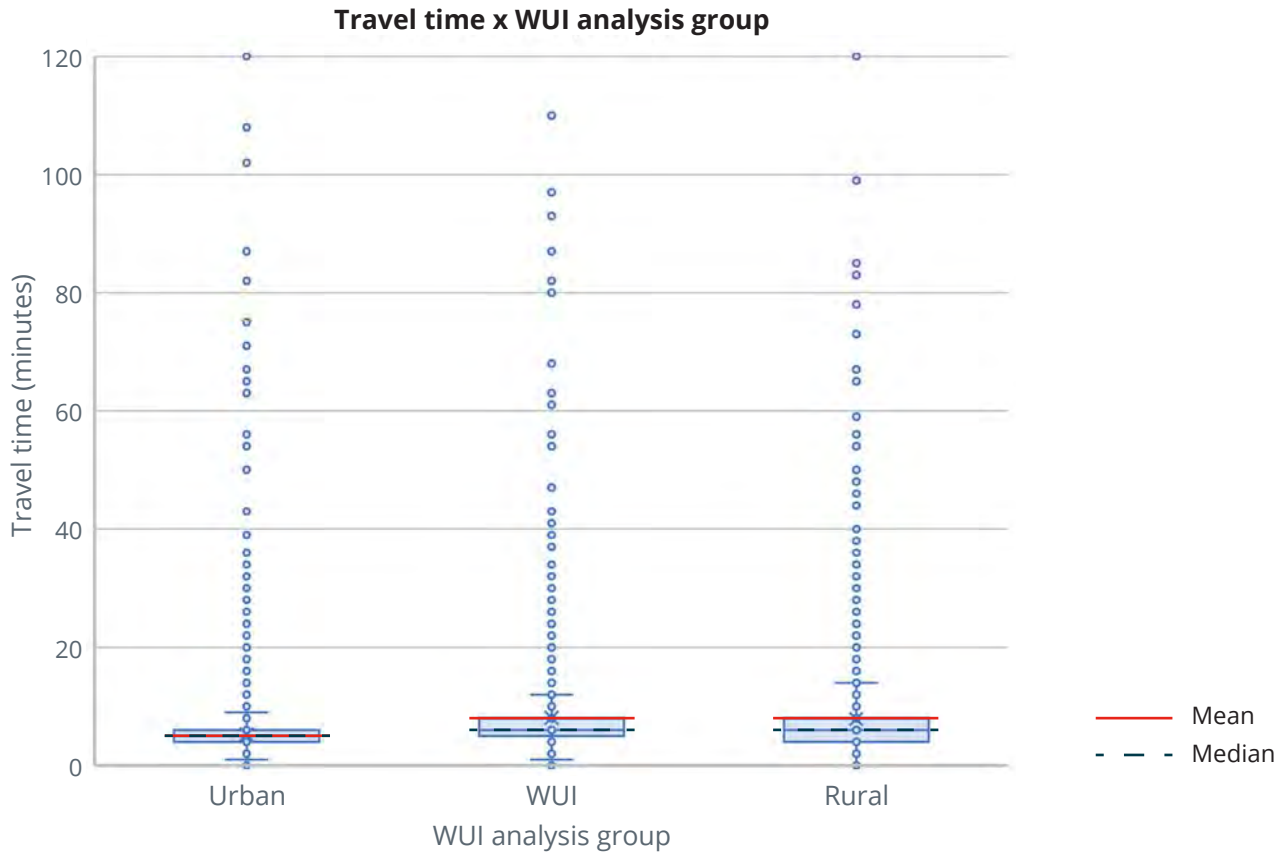
Travel time was calculated for each incident by subtracting "arrival time" from "alarm time." Any travel times over 1,440 minutes (1 day) were disregarded as erroneous. The travel time to fire incidents in WUI areas was 20% (median) to 53% (mean) longer than in urban areas (Table 5). WUI areas' travel time was on par with that of rural areas. The variation in these travel times can be visualized in the boxplot in Figure 4. In the boxplot, the mean is represented by the red horizontal line and the median value is represented by the blue dashed horizontal line, with the 25th and 75th percentiles represented by the bounds of the light blue boxes.

Table 5. Median and mean travel time for NFIRS incidents by area type, California 2009-2011, building and other structure fires, primary incidents, Incident Types 111-112

Area type	Median travel time (minutes)	Mean travel time (minutes)	Standard deviation
Urban	5	5.3	18.1
WUI	6	8.1	33.8
Rural	6	7.9	19.6

Note: Any travel times in excess of 24 hours (1,440 minutes) were removed from analysis.

Figure 4. Distribution of travel time for NFIRS incidents by area type, California 2009-2011, building and other structure fires, primary incidents, Incident Types 111-112



Note: Any travel times in excess of 24 hours (1,440 minutes) were removed from analysis. For ease of presentation, travel times greater than 2 hours (120 minutes) are not shown in this graphic.

Loss measures

Dollar loss. Accounting for missing loss data, the total imputed losses for building and other structure fires in WUI areas total $463.9 million or an average of $154.6 million per year, as seen in Table 6.

Fire incidents in WUI areas tend to have more underreported loss data in NFIRS. The total imputed costs for fires in WUI areas is 9.7% higher compared to the reported losses, whereas the average imputed loss across all regions was 6.1% (Table 6).

Table 6. Reported and imputed loss for NFIRS incidents by area type, California 2009-2011, building and other structure fires, primary incidents, Incident Types 111-112

Area type	Total reported loss ($M)	Total imputed loss ($M)	% change
Urban	851.7	890.3	4.5
WUI	423.0	463.9	9.7
Rural	358.2	378.3	5.6
Total	1,632.8	1732.6	6.1

The median imputed loss for building and other structure fires in WUI areas is 33% higher than urban areas and 14% higher than rural areas (Table 7).

Table 7. Median imputed loss of NFIRS incidents by area type, California 2009-2011, building and other structure fires, primary incidents, Incident Types 111-112

Area type	Median reported loss ($M)	Median imputed loss ($M)
Urban	5,000	6,000
WUI	5,000	8,000
Rural	5,000	7,000

There appears to be a relationship between longer travel times and increased dollar loss. Travel times to building and other structure fire incidents are longer in WUI and rural areas (Table 5) and the respective per fire dollar losses are greater (Table 8).

Table 8. Reported and imputed loss per incident for NFIRS incidents by area type, California 2009-2011, building and other structure fires, primary incidents, Incident Types 111-112

Area type	Average reported loss per fire	Average imputed loss per fire
Urban	$54,582	$57,059
WUI	$58,427	$64,087
Rural	$83,975	$88,699
Overall	$60,233	$63,914

Casualties. The more densely populated urban areas have over 2 1/2 times the casualties (injuries and deaths) in building and other structure fire incidents as WUI areas and over 5 times the casualties as rural areas (Table 9).

Table 9. Reported deaths and injuries for NFIRS incidents by area type, California 2009-2011, building and other structure fires, primary incidents, Incident Types 111-112

Area type	Firefighter deaths	Firefighter injuries	Civilian deaths	Civilian injuries	Total casualties
Urban	0	249	119	653	1,021
WUI	0	132	66	196	394
Rural	0	55	18	119	192

When the number of incidents for each area type are considered, however, building and other structure fire incidents in WUI areas have higher rates of firefighter injuries and civilian deaths than urban or rural areas. Civilian fire injury rates in WUI areas, however, are the lowest of the 3 areas (Table 10). This may be a further impact of travel times where civilians are more likely to die from an incident that requires longer travel times than suffer an injury.

Table 10. NFIRS death and injury rates by area type, California 2009-2011, building and other structure fires, primary incidents, Incident Types 111-112

Area type	Firefighter deaths/100 fires	Firefighter injuries/100 fires	Civilian deaths/100 fires	Civilian injuries/100 fires	Total casualties/100 fires
Urban	0	1.6	0.8	4.2	6.5
WUI	0	1.8	0.9	2.7	5.4
Rural	0	1.3	0.4	2.8	4.5

Mobile structure fires

Mobile structures are defined in NFIRS as mobile property used as a fixed structure. The group includes mobile homes, motor homes, camping trailers and portable buildings. Mobile structure fire incidents are much less common than building and other structure fire incidents. There were 513 mobile structure fire incidents in WUI areas in California over the study period (Table 11). These incidents represent 36% of all mobile structure fire incidents.

Table 11. NFIRS incidents by area type, California 2009-2011, mobile structure fires, primary incidents, Incident Types 120-123

Area type	Mobile, Other (120)		Mobile Home (121)		Motor Home (122)		Portable Bldg. (123)		Total	
	Incidents	Percent	Incidents	Percent	Incidents	Percent	Incidents	Percent	Incidents	Percent
Urban	43	30.9	194	29.6	182	40.0	76	44.2	495	34.8
WUI	44	31.7	275	42.0	149	32.7	45	26.2	513	36.1
Rural	52	37.4	186	28.4	124	27.3	51	29.7	413	29.1
Total	139	100.0	655	100.0	455	100.0	172	100.0	1,421	100.0

Travel time

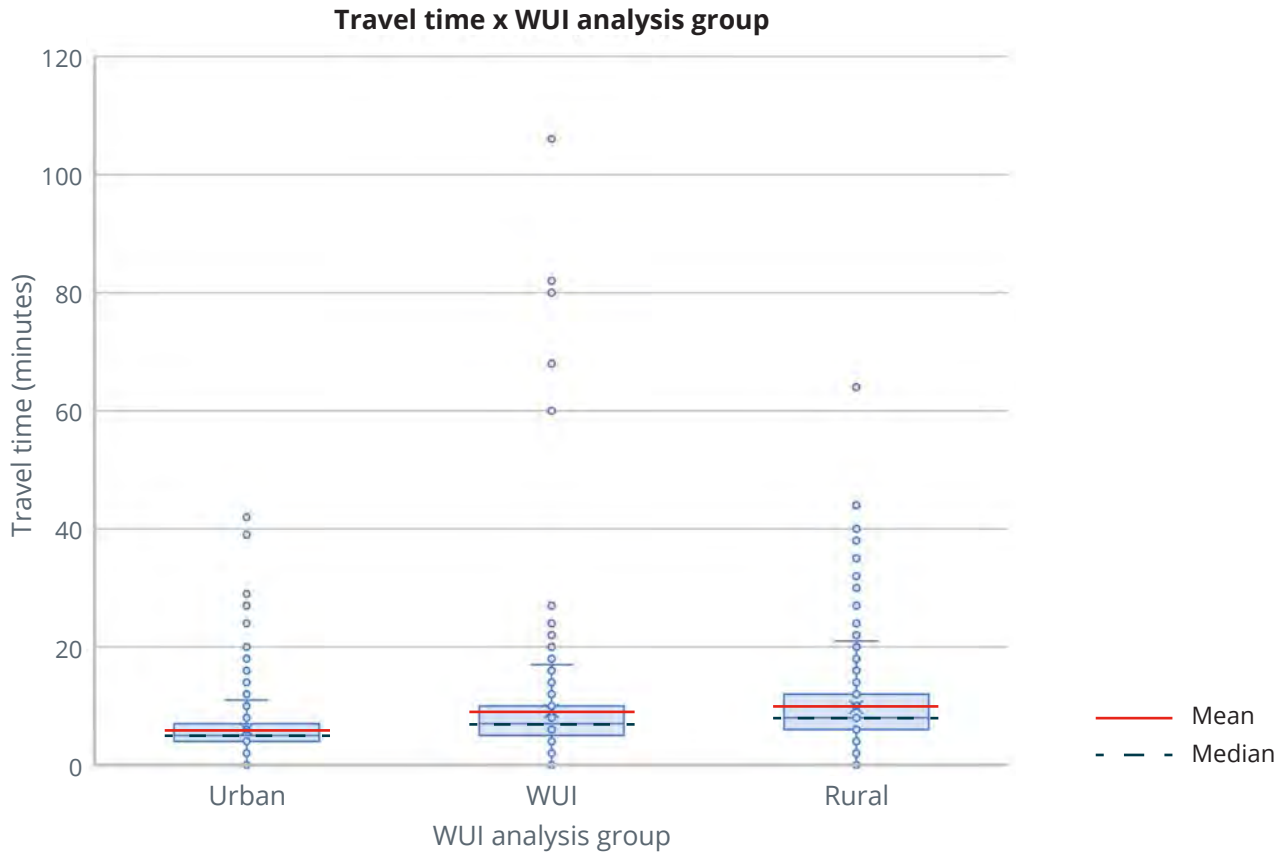
Travel time to mobile structure fire incidents in WUI areas in California was 40% (median) to 53% (mean) longer than in urban areas and 13% to 6% shorter than in rural areas (Table 12). The variation in these travel times can be visualized in the boxplot in Figure 5.

Table 12. Median and mean travel time for NFIRS incidents by area type, California 2009-2011, mobile structure fires, primary incidents, Incident Types 120-123

Area type	Median travel time (minutes)	Mean travel time (minutes)	Standard deviation
Urban	5	6.0	3.9
WUI	7	9.2	8.8
Rural	8	9.8	7.1

Note: Any travel times in excess of 24 hours (1,440 minutes) were removed from analysis.

Figure 5. Distribution of travel time for NFIRS incidents by WUI group, California 2009-2011, mobile structure fires, primary incidents, Incident Types 120-123



Note: Any travel times in excess of 24 hours (1,440 minutes) were removed from analysis. For ease of presentation, travel times greater than 2 hours (120 minutes) are not shown in this graphic.

Loss measures

Dollar loss. Total imputed losses for mobile structure fires in WUI areas, the highest of the 3 areas, totaled $8.9 million over the 3 years, averaging $3 million per year (Table 13).

Table 13. Reported and imputed loss for NFIRS incidents by area type, California 2009-2011, mobile structure fires, primary incidents, Incident Types 120-123

Area type	Total reported loss ($M)	Total imputed loss ($M)	% change
Urban	7.2	7.9	9.7
WUI	8.4	8.9	6.0
Rural	7.5	8.2	9.3
Total	23.2	25.0	7.8

Note: Totals may not add up to 100% due to rounding.

The median loss for mobile structure fires in WUI areas is 25% (imputed) to 40% (reported) higher than urban areas and on par with rural areas for imputed loss (Table 14). Similar to building and other structure fires, there appears to be a linkage between longer travel times to mobile structure fire incidents' dollar loss (Table 15).

Table 14. Median imputed loss of NFIRS incidents by area type, California 2009-2011, mobile structure fires, primary incidents, Incident Types 120-123

Area type	Median reported loss ($M)	Median imputed loss ($M)
Urban	$2,500	$4,000
WUI	$3,500	$5,000
Rural	$2,500	$5,500

Table 15. Reported and imputed loss per incident for NFIRS incidents by area type, California 2009-2011, mobile structure fires, primary incidents, Incident Types 120-123

Area type	Average reported loss per fire	Average imputed loss per fire
Urban	$14,641	$15,909
WUI	$16,461	$17,388
Rural	$18,154	$19,858
Overall	$16,319	$17,591

Casualties. Mobile structure fire incidents in WUI areas have slightly more casualties than those in urban and rural areas (Table 16). The numbers of reported casualties are small, and comparisons may not be fully valid.

Table 16. Reported deaths and injuries for NFIRS incidents by area type, California 2009-2011, mobile structure fires, primary incidents, Incident Types 120-123

Area type	Firefighter deaths	Firefighter injuries	Civilian deaths	Civilian injuries	Total casualties
Urban	0	4	7	12	23
WUI	0	1	5	19	25
Rural	0	1	3	14	18

When the number of fire incidents for each area type is considered, however, mobile structure fire incidents in WUI areas have higher casualty rates, collectively, than urban or rural areas. The firefighter injury rate for mobile structure fires is highest in urban areas as is the civilian fire death rate (Table 17). As the sample is small for these casualties, comparisons need to be made with caution.

Table 17. Death and injury rates by area type, California 2009-2011, mobile structure fires, primary incidents, Incident Types 120-123

Area type	Firefighter deaths/ 100 fires	Firefighter injuries/ 100 fires	Civilian deaths/ 100 fires	Civilian injuries/ 100 fires	Total casualties/ 100 fires
Urban	0.0	0.8	1.4	2.4	4.7
WUI	0.0	0.2	1.0	3.7	4.9
Rural	0.0	0.2	0.7	3.4	4.4

Vehicle fires

There are a sizable number of vehicle fire incidents over the study period (Table 18). There were 7,200 vehicle fire incidents in WUI areas, representing 20% of all vehicle fires (Table 19).

Table 18. NFIRS incidents by area type, California 2009-2011, vehicle fires, primary incidents, Incident Types 130-138

Area type	Mobile Prop Vehicle, Other (130)	Passenger Vehicle (131)	Transport Vehicle (132)	Rail Vehicle (133)	Water Vehicle (134)	Aircraft (135)	Self-Propelled RV (136)	Camper (137)	Off-Road/ Heavy Equip (138)	Total
Urban	1,367	14,820	511	17	77	7	39	154	94	17,086
WUI	693	5,716	357	10	62	4	59	202	97	7,200
Rural	1,002	9,436	882	35	82	33	49	193	243	11,955
Total	3,062	29,972	1,750	62	221	44	147	549	434	36,241

Table 19. Distribution of NFIRS incidents by area type, California 2009-2011, vehicle fires, primary incidents, Incident Types 130-138

Area type	Mobile Prop Vehicle, Other (130)	Passenger Vehicle (131)	Transport Vehicle (132)	Rail Vehicle (133)	Water Vehicle (134)	Aircraft (135)	Self-Propelled RV (136)	Camper (137)	Off-Road/ Heavy Equip (138)	Total
Urban	44.6%	49.4%	29.2%	27.4%	34.8%	15.9%	26.5%	28.1%	21.7%	47.1%
WUI	22.6%	19.1%	20.4%	16.1%	28.1%	9.1%	40.1%	36.8%	22.4%	19.9%
Rural	32.7%	31.5%	50.4%	56.5%	37.1%	75.0%	33.3%	35.2%	56.0%	33.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Travel time

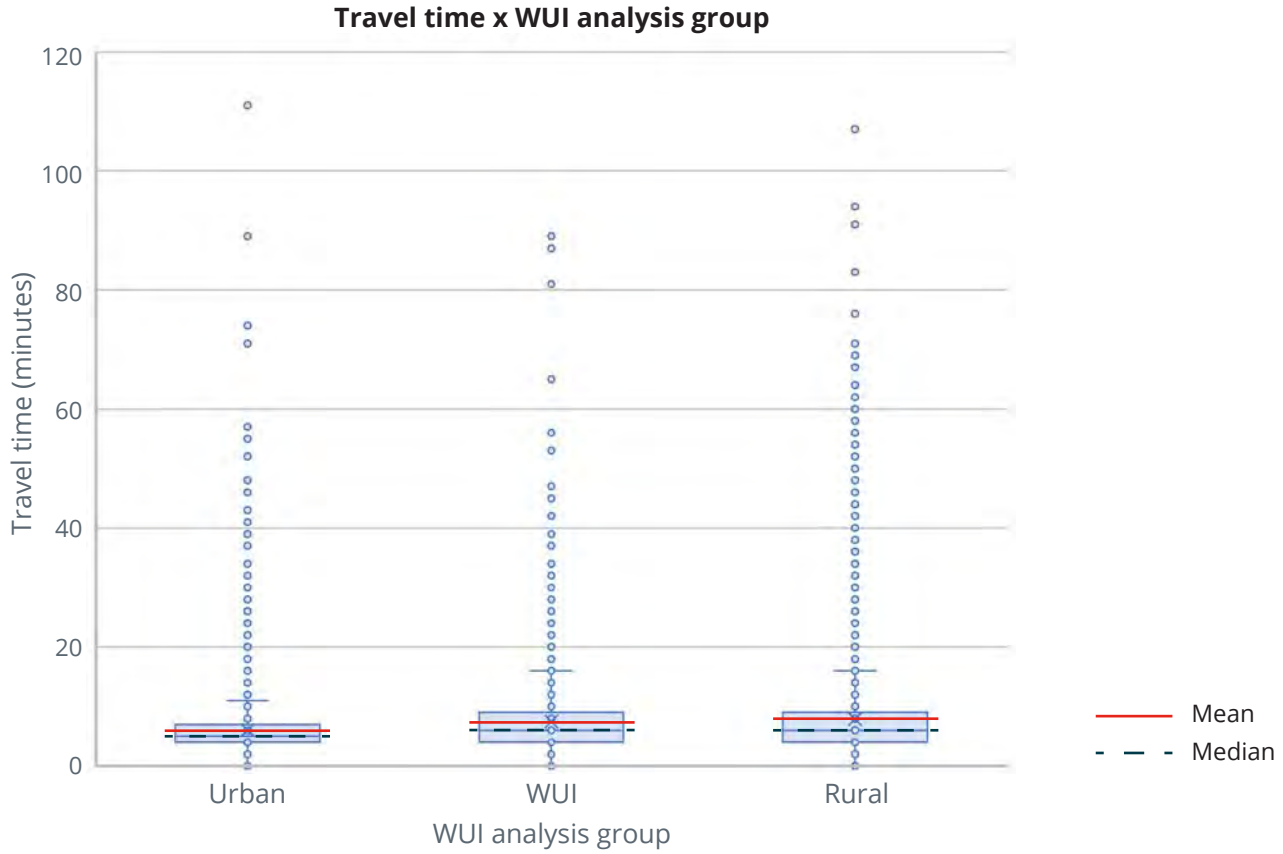
The median travel time to vehicle fire incidents in rural and WUI areas was similar to urban areas. However, the mean travel time to these areas was 24% longer for WUI areas and 30% longer for rural areas than for urban areas (Table 20). The variation in these travel times can be visualized in the boxplot in Figure 6. The difference between median and mean in the urban, rural and WUI areas is due to the presence of more outliers or extreme observations in the rural and WUI areas.

Table 20. Median and mean travel time for NFIRS incidents by area type, California 2009-2011, vehicle fires, primary incidents, Incident Types 130-138

Area type	Median travel time (minutes)	Mean travel time (minutes)	Standard deviation
Urban	5	6.0	16.2
WUI	6	7.5	15.7
Rural	6	7.9	11.5

Note: Any travel times in excess of 24 hours (1,440 minutes) were removed from analysis.

Figure 6. Distribution of travel time for NFIRS incidents by WUI group, California 2009-2011, vehicle fires, primary incidents, Incident Types 130-138



Note: Any travel times in excess of 24 hours (1,440 minutes) were removed from analysis. For ease of presentation, travel times greater than 2 hours (120 minutes) are not shown in this graphic.

Loss measures

Dollar loss. Total imputed losses for vehicle fire incidents in WUI areas totaled $58.1 million over the 3 years, averaging $19.4 million per year (Table 21). Unlike losses for fixed or mobile structure fires, the median losses for vehicle fires in WUI areas are similar to both urban and rural areas (Table 22). As noted earlier, there appears to be a relationship between longer travel times and increased dollar loss. The loss per fire is greater in WUI areas than in urban areas. Rural incidents, however, have substantially higher per-incident losses (Table 23) as the result of the predominance of a small number of aircraft incidents (Table 24).

Table 21. Reported and imputed loss for NFIRS incidents by area type, California 2009-2011, vehicle fires, primary incidents, Incident Types 130-138

Area type	Total reported loss ($M)	Total imputed loss ($M)	% change
Urban	111.7	119.8	7.2
WUI	52.4	58.1	10.9
Rural	187.2	195.8	4.6
Total	351.3	373.7	6.4

Table 22. Median imputed loss of NFIRS incidents by area type, California 2009-2011, vehicle fires, primary incidents, Incident Types 130-138

Area type	Median reported loss ($M)	Median imputed loss ($M)
Urban	2,600	3,000
WUI	2,000	3,000
Rural	3,000	3,000

Table 23. Reported and imputed loss per incident for NFIRS incidents by area type, California 2009-2011, vehicle fires, primary incidents, Incident Types 130-138

Area type	Average reported loss per incident ($M)	Average imputed loss per incident ($M)
Urban	6,537	7,011
WUI	7,283	8,075
Rural	15,658	16,376
Overall	9,694	10,312

Table 24. Reported and imputed loss for aircraft and non-aircraft NFIRS incidents by area type, California 2009-2011, vehicle fires, primary incidents, Incident Types 130-138

Area type	Incidents		Average reported loss per incident ($M)		Average imputed loss per incident ($M)		Median reported loss ($M)		Median imputed loss ($M)	
	Aircraft	Non-aircraft	Aircraft	Non-aircraft	Aircraft	Non-aircraft	Aircraft	Non-aircraft	Aircraft	Non-aircraft
Urban	7	17,079	530,857	6,322	534,429	6,795	19,500	2,600	20,000	3,000
WUI	4	7,196	21,250	7,276	36,250	8,059	7,500	2,000	30,000	3,000
Rural	33	11,922	2,150,409	9,749	2,151,758	10,465	10,000	3,000	8,500	3,000
Overall	44	36,197	1,699,193	7,640	1,702,136	8,255	10,000	2,500	12,500	3,000

Casualties. Vehicle fire incidents in WUI areas have similar death or injury rates per 100 fires compared to those in urban and rural areas (Table 25).

Table 25. Reported deaths and injuries for NFIRS incidents by area type, California 2009-2011, vehicle fires, primary incidents, Incident Types 130-138

Area type	Firefighter deaths	Firefighter injuries	Civilian deaths	Civilian injuries	Total injuries or deaths
Urban	0	17	33	71	121
WUI	0	6	12	25	43
Rural	0	11	28	27	66

When the number of incidents for each area type are considered, however, civilian injuries due to vehicle fires occur in WUI areas less frequently than in urban areas but more frequently than in rural areas (Table 26). Note, these numbers are small and inferences about rates should be considered with caution.

Table 26. Death and injury rates by area type, California 2009-2011, vehicle fires, primary incidents, Incident Types 130-138

Area type	Firefighter deaths/ 100 fires	Firefighter injuries/ 100 fires	Civilian deaths/ 100 fires	Civilian injuries/ 100 fires	Total casualties/ 100 fires
Urban	0	0.1	0.2	0.4	0.7
WUI	0	0.1	0.2	0.3	0.6
Rural	0	0.1	0.2	0.2	0.6

Fire cause

Within NFIRS, the cause of fire is determined by using a hierarchical set of rules based on the reported fire-related data. Currently, this cause is only calculated for structure fires (Incident Types 111-123: buildings, other structures, building fires contained to noncombustible containers, and mobile structures). This data can be combined with the geographic classification methodology as described above to analyze fire incident cause within the WUI. NFIRS has a special classification for fires in buildings that are confined to noncombustible containers (Incident Types 113-118). The causes of these fires are examined separately below.

The primary causes for nonconfined structure fires within the WUI, other than unknown, are electrical malfunction; other unintentional, careless actions; and open flame (Table 27). Percentages for some causes stand out in the WUI. For nonconfined structures, fires in WUI areas are less likely to have a cause of intentional or exposure than incidents in rural or urban areas. Fires in WUI areas are more likely to be caused by heating, cooking, appliances, open flame and cause under investigation than those in rural or urban areas.

Table 27. NFIRS reported incidents by cause by area type, California 2009-2011, nonconfined structure fires, primary incidents, Incident Types 111-112 and 120-123

Cause	Urban		WUI		Rural		Total	
	Incidents	Percent	Incidents	Percent	Incidents	Percent	Incidents	Percent
01-Intentional	1,327	8.2	453	5.8	406	8.7	2,186	7.7
02-Playing with Heat Source	124	0.8	54	0.7	21	0.4	199	0.7
03-Smoking	679	4.2	200	2.6	106	2.3	985	3.5
04-Heating	455	2.8	316	4.1	129	2.8	900	3.2
05-Cooking	451	2.8	261	3.4	78	1.7	790	2.8
06-Electrical Malfunction	2,179	13.5	1,075	13.9	693	14.8	3,947	13.8
07-Appliances	661	4.1	390	5.0	200	4.3	1,251	4.4
08-Open Flame	1,269	7.9	675	8.7	276	5.9	2,220	7.8
09-Other Heat	1,187	7.4	511	6.6	300	6.4	1,998	7.0
10-Other Equipment	360	2.2	196	2.5	147	3.1	703	2.5
11-Natural	281	1.7	175	2.3	108	2.3	564	2.0
12-Exposure	665	4.1	295	3.8	266	5.7	1,226	4.3
13-Unknown	3,286	20.4	1,674	21.6	1,099	23.5	6,059	21.2
14-Equipment Malfunction, Failure	1,208	7.5	575	7.4	339	7.2	2,122	7.4
15-Other Unintentional, Careless	1,800	11.2	797	10.3	463	9.9	3,060	10.7
16-Cause Under Investigation	167	1.0	105	1.4	47	1.0	319	1.1
Total	16,099	100.0	7,752	100.0	4,678	100.0	28,529	100.0

Less likely[14] More likely

[14]The relative likelihood of structure fire causes in the WUI area was determined by comparing the percentage of a given cause across the 3 area types. The cause of fires in the WUI was deemed less likely if it had the lowest percentage of fires across the 3 area types; conversely, it was deemed more likely if it had the highest percentage of fires across the 3 area types.

This data can be segregated to only examine building and other structure fires. The primary causes for building and other structure fires within the WUI, other than unknown, are electrical malfunction; other unintentional, careless actions; and open flame (Table 28).

For structure and other building fires, the WUI is less likely to have intentional, other heat, other equipment, and exposure fire causes than incidents in rural or urban areas. For structure and other building fires, the WUI is more likely to have heating, cooking, appliances, open flame, equipment malfunction/failure, and cause under investigation fires than rural or urban areas.

Table 28. NFIRS reported incidents by cause by area type, California 2009-2011, buildings and other structures, primary incidents, Incident Types 111-112

Cause	Urban		WUI		Rural		Total	
	Incidents	Percent	Incidents	Percent	Incidents	Percent	Incidents	Percent
01-Intentional	1,269	8.1	426	5.9	375	8.8	2,070	7.6
02-Playing with Heat Source	123	0.8	52	0.7	21	0.5	196	0.7
03-Smoking	672	4.3	186	2.6	98	2.3	956	3.5
04-Heating	449	2.9	287	4.0	106	2.5	842	3.1
05-Cooking	444	2.8	249	3.4	70	1.6	763	2.8
06-Electrical Malfunction	2,125	13.6	1,005	13.9	653	15.3	3,783	14.0
07-Appliances	644	4.1	374	5.2	183	4.3	1,201	4.4
08-Open Flame	1,241	8.0	643	8.9	250	5.9	2,134	7.9
09-Other Heat	1,169	7.5	478	6.6	288	6.8	1,935	7.1
10-Other Equipment	282	1.8	126	1.7	105	2.5	513	1.9
11-Natural	276	1.8	169	2.3	104	2.4	549	2.0
12-Exposure	631	4.0	272	3.8	230	5.4	1,133	4.2
13-Unknown	3,187	20.4	1,571	21.7	991	23.2	5,749	21.2
14-Equipment Malfunction, Failure	1,168	7.5	549	7.6	314	7.4	2,031	7.5
15-Other Unintentional, Careless	1,765	11.3	758	10.5	433	10.2	2,956	10.9
16-Cause Under Investigation	159	1.0	94	1.3	44	1.0	297	1.1
Total	15,604	100.0	7,239	100.0	4,265	100.0	27,108	100.0

Less likely More likely

For confined fires, when only the known causes are considered, the 4 leading causes (intentional, smoking, heating and cooking) account for 92% of confined fires. In WUI areas, heating is more likely to be the cause of a confined fire than in urban or rural areas — the percentage for confined heating fires is 5 times that of urban areas and over 3 times that of rural areas. Conversely, intentional and smoking are less likely to be the cause of a confined fire in WUI areas than in urban or rural areas (Table 29).

Table 29. Reported NFIRS incidents by cause by area type, California 2009-2011, confined building fires, primary incidents, Incident Types 113-118

Cause	Urban		WUI		Rural		Total	
	Incidents	Percent	Incidents	Percent	Incidents	Percent	Incidents	Percent
01-Intentional	1,110	5.6	243	4.4	328	6.6	1,681	5.5
03-Smoking	630	3.2	72	1.3	256	5.1	958	3.2
04-Heating	871	4.4	1,193	21.7	295	5.9	2,359	7.8
05-Cooking	12,275	61.8	2,801	50.8	1,973	39.5	17,049	56.1
13-Unknown	3,691	18.6	930	16.9	1,680	33.6	6,301	20.7
All Other Causes	1,298	6.5	271	4.9	469	9.4	2,038	6.7
Total	19,875	100.0	5,510	100.0	5,001	100.0	30,386	100.0

Less likely More likely

Exposure fires

An exposure is a fire that results from another fire incident.[15] This exposure data can be combined with the geographic classification methodology as described above to analyze the characteristics of exposure fires within the WUI. Exposure fires are not common: in the analysis dataset, only 1% of fires were the originating fire and another 2% were the resulting exposure fire.

Of primary interest in analyzing exposure fires is the originating incident type to discover the root cause of the fire that spread to multiple incidents. To analyze this data, any incident that is marked as an exposure is joined by the state, fire department, fire department identification number, incident date and incident number with its "parent" or originating nonexposure incident. Instances where no parent could be identified are separated out in the analysis in the category of "Missing Originating Fire."[16]

The distribution of the incident type of the originating fires is shown in Table 30. Across the area types, structure and vehicle fires are by far the most common source of exposure fires and, on average, account for 64% of the originating fires. These fires are slightly less likely to be the source of exposures in the WUI where they account for 61% of WUI area fires. Within the WUI, mobile structure fires and vegetation fires are more likely to be the originating incident type compared with rural or urban areas. Vegetation fires in the WUI are twice as likely to have been the exposure source than for urban areas.

[15]Exposure fires in NFIRS are fully defined as "A fire in a building, structure, vehicle, or outside property resulting from a fire outside that building, structure, vehicle, or outside property."

[16]Missing originating fires fall into 2 categories: those with insufficient address information to have been geocoded and included in the dataset and those that were not included in the public data.

Table 30. NFIRS originating incident type for incidents with exposures by area type, California 2009-2011, primary incidents, Incident Types 100-173

Originating incident type	Urban		WUI		Rural		Total	
	Incidents	Percent	Incidents	Percent	Incidents	Percent	Incidents	Percent
11x - Structure Fire	368	36.7	131	31.8	93	25.9	592	34.3
12x - Mobile Structure	13	1.3	21	5.1	11	3.1	45	2.9
13x - Vehicle	289	28.8	119	28.9	138	38.4	546	28.2
14x - Vegetation	81	8.1	71	17.2	57	15.9	209	12.3
15x - Rubbish	174	17.4	42	10.2	34	9.5	250	10.6
16x - Special Outside	41	4.1	20	4.9	18	5.0	79	4.9
17x - Crop	5	0.5	2	0.5	3	0.8	10	1.1
100 - Other Fire	31	3.1	6	1.5	5	1.4	42	2.1
Missing Originating Fire							68	3.6
Total	1,002	100.0	412	100.0	359	100.0	1,841	100.0

■ More likely

The 1,841 originating fires generated 3,019 exposure fires. By identifying the origin exposure fire and the analysis group where it originated, the data can be further grouped by originating area (Table 31). Generally, the originating fire generates exposure fires in the same area: 92% of urban exposure fires originate in urban areas and 90% of WUI exposure fires originate in the WUI. Rural, though, appears to have a slightly different distribution: only 81% of rural exposure fires originate as a rural incident. Additional detail about the incident type of the exposure fire is included in the Appendix.

Table 31. NFIRS originating and exposure incident area for incidents with exposures by area type, California 2009-2011, primary incidents, Incident Types 100-173

Originating incident area	Exposure incident area							
	Urban		WUI		Rural		Total	
	Incidents	Percent	Incidents	Percent	Incidents	Percent	Incidents	Percent
Urban	1,475	91.8	17	2.5	57	7.8	1,549	51.3
WUI	28	1.7	613	90.1	50	6.8	691	22.9
Rural	49	3.0	24	3.5	596	81.4	669	22.2
Missing Originating Fire*	55	3.4	26	3.8	29	4.0	110	3.6
Total*	**1,607**	**100.0**	**680**	**100.0**	**732**	**100.0**	**3,019**	**100.0**

*The 68 missing originating fires from Table 30 generated 110 exposure fires.

Conclusion

Using the method described, it is possible to identify NFIRS incidents in the WUI by combining their geographical coordinates with USFS shapefiles that identify their WUI classification. The use of this technique can be used broadly to analyze NFIRS data and draw a number of observations about NFIRS data and the WUI. Some of the conclusions drawn about fires in WUI areas may shape recommendations for how to mitigate the risk from fire in the WUI.

Important observations that result from this study are:

- Median travel times to fire incidents in the WUI for structures and other buildings are 20% longer than those for urban fire incidents, appear to result in 33% higher median losses, and have higher rates of firefighter injuries and civilian deaths.
- Median travel times to fire incidents in the WUI for mobile structures are 40% longer than those for urban incidents, appear to result in 25% higher median losses, and may have slightly higher casualty rates.
- Median travel times to fire incidents in the WUI for vehicles are similar to those for urban fire incidents, appear to result in similar median losses, and may have slightly lower rates of deaths or injuries.
- Overall, nonconfined structure fire incidents in WUI areas are caused by electrical malfunction; other unintentional, careless actions; and open flame. Nonconfined structure fires in WUI areas are less likely to have a cause of intentional or exposure than incidents in rural or urban areas. Nonconfined structure fires in WUI areas are more likely to be caused by heating, cooking, appliances, open flame and cause under investigation than those in rural or urban areas.
- Small, confined fires in WUI areas are more likely to be caused by heating than in urban or rural areas. Confined heating fires are 5 times more likely in WUI areas than urban areas and over 3 times more likely than rural areas.
- Fires in WUI areas that are exposures from other fire incidents are more likely to have resulted from vegetation or mobile structure fires than in urban or rural areas. Structure and vehicle fires still account for 61% of the originating fires in the WUI.
- Overall, originating fires generate exposure fires in the same area: 92% of urban exposure fires originate in urban areas, 90% of WUI exposure fires originate in the WUI and 81% of rural exposure fires originate as a rural incident. There appears to be little overlap in fire generation between areas.

Limitations

NFIRS does not record geographic coordinates (latitude and longitude) of an incident within the Basic Module, and incidents must be geocoded based on the address or location information provided by the fire department. Depending on the completeness and accuracy of the address/location information and limitations on the encoding algorithm, the geocoding algorithm may not be able to determine latitude and longitude for an incident with a high degree of precision. Some incident locations may only be identified at a broad level of accuracy and therefore be assigned coordinates that correspond to the center of a city or ZIP code if the information needed for a more precise determination is missing or inaccurate. Some incidents cannot be geocoded with any level of precision and are discarded from the dataset. This could affect conclusions about medians and means of the remaining population.

The study was focused on incidents exclusively in California as reported to NFIRS. Observations about populations, travel time and property loss may not be applicable to other states.

The most recent USFS WUI shapefiles are from 2010. Observations about populations, travel time and property loss may have changed since that date.

Future work

The inability to successfully geocode many NFIRS incidents is a constraint on many geographic-based analyses. More accurate geocoding of incidents could add a substantial number of additional incidents to the study. An outreach program to encourage NFIRS departments to correctly record address information and standardize input of other types of location information, or NFIRS modifications to allow fire departments to submit geographic coordinates would be beneficial. Enabling NFIRS to accept polygon-based geographic data in addition to the current point data would enable better analysis of geographically large incidents.

Expanding the study to additional states beyond California is suggested to see if observations about populations, travel time, and property loss are applicable to other states. California has unique geographic and climate considerations that may result in WUI fire patterns distinctive to California.

It may be possible to create custom WUI shapefiles using more recent data than that which is available from the USFS. These custom shapefiles would allow for observations about populations, travel time and property loss that are more current.

Further analysis into the relationships between travel times and losses, in particular for building and structure fires, is warranted to see what factors may influence structure fire losses. For dollar loss, including real estate cost factors, if available, might be beneficial. Expanding the analyses to include Fire Module data for structures might also provide insight into losses in the WUI.

References

Butry, D., & Thomas, D. S. (2017, January). Underreporting of wildland fires in the US Fire Reporting System NFIRS: California. *International Journal of Wildland Fire,* 26(8), 732.

Calkin, D. E., Cohen, J. D, Finney, M. A., & Thompson, M. P. (2014, January). How risk management can prevent future wildfire disasters in the wildland-urban interface. *PNAS, 111*(2), 746–751.

Federal Emergency Management Agency. (2011, October). *NFIRS representativeness study.* https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiW_aK64dHpAhXSmeAKHTJBDjEQFjAAegQIARAB&url=https%3A%2F%2Fwww.reginfo.gov%2Fpublic%2Fdo%2FDownloadDocument%3FobjectID%3D53926600&usg=AOvVaw3OOIsiworPgF_tJhqW1HNK

Fox, D., Carrega, P., Adnès, C., Emsellem, K., Ganga, O., Tortorollo, N., Martin, N., Andrieu, J, Moebius, F., & Fox, E. A. (2015, January). Increases in fire risk due to warmer summer temperatures and wildland urban interface changes do not necessarily lead to more fires. *Applied Geography, 56*, 1–12.

National Interagency Fire Center. (2018). Wildland fire summary and statistics annual report 2018. *National Interagency Coordination Center.* https://www.predictiveservices.nifc.gov/intelligence/2018_statssumm/intro_summary18.pdf

National Interagency Fire Center. (2019). Wildland fire summary and statistics annual report 2019. *National Interagency Coordination Center.* https://www.predictiveservices.nifc.gov/intelligence/2019_statssumm/intro_summary19.pdf

Radeloff, V. C., Hammer, R. B., Stewart, S. I., Fried, J. S., Holcomb, S. S., & McKeefry, J. F. (2005). The wildland-urban interface in the United States. *Ecological Applications, 15*(3), 799–805.

Radeloff, V. C., Helmers, D. P., Kramer, H. A., Mockrin, M. H., Alexandre, P. M., Bar-Massada, A., Butsic, V., Hawbaker, T. J., Martinuzzi, S., Syphard, A. D., & Stewart, S. I. (2017). *The 1990-2010 wildland-urban interface of the conterminous United States - geospatial data.* USDA Data Archive.

Radeloff, V. C., Helmers, D. P., Kramer, H. A., Mockrin, M. H., Alexandre, P. M., Bar-Massada, A., Butsic, V., Hawbaker, T. J., Martinuzzi, S., Syphard, A. D., & Stewart, S. I. (2018). Rapid growth of the US wildland-urban interface raises wildfire risk. *PNAS,* 3314–3319.

Romero-Calcerrada, R., Barrio-Parra, F., Millington, J. D. A., & Novillo, C. J. (2010). Spatial modelling of socioeconomic data to understand patterns of human-caused wildfire ignition risk in the SW of Madrid (central Spain). *Ecological Modelling, 221*(1), 34–45.

Runyan, C. W., Bangdiwala, S. I., Linzer, M. A., Sacks, J. J., & Butts, J. (1993, May). Risk factors for fatal residential fires. *Fire Technology, 29,* 183–193.

Runyan, C. W., Johnson, R., Yang, J., Waller, A. E., Perkis, D., Marshall, S. W., Coyne-Beasley, T., & Mcgee, K. S. (2005, February). Risk and protective factors for fires, burns, and carbon monoxide poisoning in U.S. households. *American Journal of Preventive Medicine, 28*(1), 102–108.

Stewart, S. I., Radeloff, V. C., Hammer, R. B., & Hawbaker, T. J. (2007, June). Defining the wildland–urban interface. *Journal of Forestry, 105*(4), 201–207.

Urban Wildland Interface Communities Within the Vicinity of Federal Lands that Are at High Risk from Wildfire, 66 F.R. 751 (January 4, 2001).

U.S. Fire Administration. (2016). *2016 PDR*. https://www.usfa.fema.gov/data/statistics/order_download_data.html

U.S. Fire Administration. (2017). *National Fire Estimation Using NFIRS Data.* https://www.usfa.fema.gov/downloads/pdf/statistics/national_fire_estimation_using_nfirs_data.pdf

U.S. Fire Administration. (2019a). *Fire in the United States 2008-2017* (20th ed.) https://www.usfa.fema.gov/downloads/pdf/publications/fius20th.pdf

U.S. Fire Administration. (2019b). *National Fire Loss Estimation Using NFIRS Data* [Draft report]. USFA.

U.S. Fire Administration. (2019c). *Wildland Fire Module: NFIRS-8*. From NFIRS 5.0 Self-Study Program. https://www.usfa.fema.gov/downloads/pdf/nfirs_q494/nfirs_module_8_wildland_fire.pdf

U.S. Fire Administration. (2021). *Investigation of MODIS-Detected Fires in NFIRS.* https://www.usfa.fema.gov/downloads/pdf/publications/investigation-of-modis-detected-fires-in-nfirs.pdf

U.S. Fire Administration, National Fire Data Center. (1997, June). *Socioeconomic factors and the incidence of fire* [Resarch report]. https://www.usfa.fema.gov/downloads/pdf/statistics/socio.pdf

U.S. Fire Administration, National Fire Data Center. (2014, March). *Data sources and methodology documentation.* http://www.usfa.fema.gov/downloads/pdf/statistics/data_sources_methodology.pdf

U.S. Fire Administration, National Fire Data Center. (September 2020). *NFIRS Wildfires 2018 - An exploratory analysis* [Draft report].

Vega-Garcia, C., Woodard, P. M., Titus, S. J., Adamowicz, L., & Let, S. (1995, January). A Logit model for predicting the daily occurrence of human caused forest fires. *International Journal of Wildland Fire, 5*(2), 101–11.

Appendix

National Fire Incident Reporting System wildland fire definitions

The NFIRS Wildland Fire Module has its own set of definitions for recording incidents (USFA, 2019). The term "wildland" as used by NFIRS is a bit of a misnomer relative to the definitions in this paper as, in practice, NFIRS Wildland Fire Module is used to record **wildfires**, not fires in the **wildland**.

- **Prescribed Fire.** Any fire ignited by management actions to meet specific objectives. A written, approved prescribed fire plan must exist prior to ignition (Incident Type 632). A prescribed fire that escapes management is a hostile fire (Incident Type 141).
- **Urban-Wildland Interface Area.** The geographical area in which structures and other human development meet or intermingle with wildland or vegetative fuels.
- **Urban-Wildland Interface Fire.** Any fire, other than prescribed fire, where fire suppression tactics were influenced by a geographical area where structures and other human development meet or intermingle with wildland or vegetative fuels.
- **Wildland.** An area in which development is essentially nonexistent, except for roads, railroads, power lines and similar facilities.
- **Wildland Fire.** Any fire, other than a prescribed fire, involving vegetative fuels that occurs in the wildland. A wildland fire may expose and possibly consume structures (Incident Type 141).

National Fire Incident Reporting System incident groupings

For the purposes of this report, NFIRS incident types are grouped as shown in Table A-1.

Table A-1. NFIRS incident type groupings

Incident type grouping	Incident Type	Incident type description
Buildings and other structures	111	Building fire
	112	Fire in structure other than in a building
Confined building	113	Cooking fire, confined to container
	114	Chimney or flue fire, confined to chimney or flue
	115	Incinerator overload or malfunction, fire confined
	116	Fuel burner/boiler malfunction, fire confined
	117	Commercial Compactor fire, confined to rubbish
	118	Trash or rubbish fire, contained
Mobile structures	120	Fire in mobile property used as a fixed structure, other
	121	Fire in mobile home used as fixed residence
	122	Fire in motor home, camper, recreational vehicle
	123	Fire in portable building, fixed location
Vehicle	130	Mobile property (vehicle) fire, other
	131	Passenger vehicle fire
	132	Road freight or transport vehicle fire
	134	Water vehicle fire
	133	Rail vehicle fire
	135	Aircraft fire
	136	Self-propelled motor home or recreational vehicle
	137	Camper or recreational vehicle (RV) fire
	138	Off-road vehicle or heavy equipment fire

Other wildfire definitions

There are many definitions in the wildland arena. The definitions are often very similar, with each agency/report using a slight variation (Table A-2). The definitions often conflate the type of fire with the location of the fire. Some definitions, however, presuppose a common understanding of an undefined term(s).

Table A-2. Wildland, WUI and wildfire terms

Source	Wildland	WUI	Wildland fire	WUI fire	Wildfire
1. National Fire Incident Reporting System 5.0 Complete Reference Guide, January 2015	An area in which development is essentially nonexistent, except for roads, railroads, power lines, and similar facilities.	The geographical area where structures and other human development meet or intermingle with wildland or vegetative fuels.	Any fire involving vegetative fuels, other than a prescribed fire, that occurs in the wildland. A wildland fire may expose and possibly consume structures (Incident Type 141).	Any fire, other than a prescribed fire, where fire suppression tactics were influenced by a geographical area where structures and other human development meet or intermingle with wildland or vegetative fuels.	
2. Wildland Urban Interface Fire Operational Requirements and Capability Analysis, May 2019, p.1		...the area where houses and wildland vegetation meet or overlap, posing an increased risk for wildfires due to human-caused ignitions and a greater risk posed to lives and property where wildfire problems are most pronounced.	Any non-structure fire, other than prescribed fire, that occurs in the wildland.	...the amalgamation where structures and human development meet with undeveloped vegetative fuels and are differentiated from structure and wildland fires.	
3. U.S. Forest Service		...where houses and other development meet or mix with undeveloped natural areas...			

Table A-2. Wildland, WUI and wildfire terms — continued

Source	Wildland	WUI	Wildland fire	WUI fire	Wildfire
4. National Fire Protection Association 1143, Standard for Wildland Fire Management, 2018 edition		3.3.22 Locations in which the AHJ [authority having jurisdiction] determines that topographical features, vegetation fuel types, local weather conditions, and prevailing winds result in the potential for ignition of the structures with the area from flames and firebrands of a wildland fire.	3.3.21 An unplanned and uncontrolled fire spreading through vegetative fuels, including any structures or other improvements thereon.		
5. National Fire Plan (2000)		...an area where structures and other human development meet or intermingle with undeveloped wildland.			
6. National Wildfire Coordinating Group	An area in which development is essentially non-existent, except for roads, railroads, powerlines, and similar transportation facilities. Structures, if any, are widely scattered.	The line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels. Describes an area within or adjacent to private and public property where mitigation actions can prevent damage or loss from wildfire.	Any non-structure fire that occurs in vegetation or natural fuels. Includes wildfires and prescribed fires.		An unplanned, unwanted wildland fire including unauthorized human-caused fires, escaped wildland fire use events, escaped prescribed fire projects, and all other wildland fires where the objective is to put the fire out (definition currently under review).

Table A-2. Wildland, WUI and wildfire terms — continued

Source	Wildland	WUI	Wildland fire	WUI fire	Wildfire
7. Federal Register		Federal agencies focus on two categories: Interface and Intermix. Interface is "where structures directly abut wildland fuels…The development density for an interface community is usually 3 or more structures per acre… An alternative definition of the interface community emphasizes a population density of 250 or more people per square mile." Intermix is "where structures are scattered throughout a wildland area…The development density in the intermix ranges from structures very close together to one structure per 40 acres…An alternative definition of intermix community emphasizes a population density of between 28-250 people per square mile."			

Sources: 1. https://www.usfa.fema.gov/downloads/pdf/nfirs/NFIRS_Complete_Reference_Guide_2015.pdf
2. https://www.dhs.gov/sites/default/files/publications/wui_fire_report_of_findings_july_24_2019v2_508.pdf
3. https://www.nrs.fs.fed.us/data/WUI
4. https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=1143
5. https://www.doi.gov/sites/doi.gov/files/migrated/pmb/owf/upload/2000-Report-to-the-President.pdf
6. https://www.nwcg.gov/about-the-nwcg-glossary-of-wildland-fire
7. https://www.federalregister.gov/documents/2001/01/04/01-52/urban-wildland-interface-communities-within-the-vicinity-of-federal-lands-that-are-at-high-risk-from

Exposure fires by incident groups and incident types

The most common exposure fire incident type groups in the WUI are structure, vehicle and vegetation fires (Table A-3).

Table A-3. NFIRS exposure fire incidents by incident type group by WUI analysis group, California 2009-2011, primary incidents, Incident Types 100-173

Incident Type	Urban	WUI	Rural	Total
11x - Structure Fire	634	249	218	1,101
12x - Mobile Structure	33	21	36	90
13x - Vehicle	573	202	306	1,081
14x - Vegetation	69	99	97	265
15x - Rubbish	121	21	27	169
16x - Special Outside	85	38	26	149
17x - Crop	9	2	9	20
100 - Other Fire	83	48	13	144
Total	1,607	680	732	3,019

Table A-4 presents the detailed breakout of exposure fires as percentages for each area type.

Table A-4. NFIRS exposure fire incidents by incident type group by WUI analysis group, California 2009-2011, primary incidents, Incident Types 100-173

Incident Type	Urban	WUI	Rural	Grand total
11x - Structure Fire	39.5%	36.6%	29.8%	36.5%
12x - Mobile Structure	2.1%	3.1%	4.9%	3.0%
13x - Vehicle	35.7%	29.7%	41.8%	35.8%
14x - Vegetation	4.3%	14.6%	13.3%	8.8%
15x - Rubbish	7.5%	3.1%	3.7%	5.6%
16x - Special Outside	5.3%	5.6%	3.6%	4.9%
17x - Crop	0.6%	0.3%	1.2%	0.7%
100 - Other Fire	5.2%	7.1%	1.8%	4.8%
Overall	100.0%	100.0%	100.0%	100.0%

Table A-5 is the detailed breakout of exposure fire incident type groups (Table A-3) by their reported individual incident types. Basing further observations or conclusions on this data may be difficult as the exposure fire data is a small subset of the reported fire data. This subset combined with the large number of incident types results in very small numbers in some of the categories.

Table A-5. NFIRS fire incidents by incident type by WUI analysis group, California 2009-2011, primary incidents, Incident Types 100-173

Incident Type	Incident type description	Urban	WUI	Rural	Total
111	Building fire	550	224	189	963
112	Fire in structure other than in a building	49	22	17	88
113	Cooking fire, confined to container	5			5
114	Chimney or flue fire, confined to chimney or flue			1	1
117	Commercial Compactor fire, confined to rubbish	1		1	2
118	Trash or rubbish fire, contained	29	3	10	42
120	Fire in mobile property used as a fixed structure, other	3	2	3	8
121	Fire in mobile home used as fixed residence	7	10	19	36
122	Fire in motor home, camper, recreational vehicle	15	8	10	33
123	Fire in portable building, fixed location	8	1	4	13
130	Mobile property (vehicle) fire, other	45	8	27	80
131	Passenger vehicle fire	499	160	204	863
132	Road freight or transport vehicle fire	15	10	34	59
134	Water vehicle fire	3	4	7	14
135	Aircraft fire			1	1
136	Self-propelled motor home or recreational vehicle	2	3	4	9
137	Camper or recreational vehicle (RV) fire	6	14	17	37
138	Off-road vehicle or heavy equipment fire	3	3	12	18
140	Natural vegetation fire, other	20	15	7	42
141	Forest, woods or wildland fire	2	3	4	9
142	Brush or brush-and-grass mixture fire	12	37	36	85
143	Grass fire	35	44	50	129
150	Outside rubbish fire, other	27	2	3	32
151	Outside rubbish, trash or waste fire	64	10	14	88
154	Dumpster or other outside trash receptacle fire	29	9	10	48
155	Outside stationary compactor/compacted trash fire	1			1
160	Special outside fire, other	36	22	10	68
161	Outside storage fire	34	11	11	56
162	Outside equipment fire	15	5	3	23
163	Outside gas or vapor combustion explosion			2	2
170	Cultivated vegetation, crop fire, other	1	1	2	4
171	Cultivated grain or crop fire	1		3	4
172	Cultivated orchard or vineyard fire	1		3	4
173	Cultivated trees or nursery stock fire	6	1	1	8
100	Other fire	83	48	13	144
Grand total		1,607	680	732	3,019

Table A-6 presents the detailed breakout of exposure fires from Table A-5 as percentages for each area type.

Table A-6. NFIRS fire incidents distribution by incident type by WUI analysis group, California 2009-2011, primary incidents, Incident Types 100-173

Incident Type	Incident type description	Urban	WUI	Rural	Total
111	Building fire	34.2%	32.9%	25.8%	31.9%
112	Fire in structure other than in a building	3.0%	3.2%	2.3%	2.9%
113	Cooking fire, confined to container	0.3%	0.0%	0.0%	0.2%
114	Chimney or flue fire, confined to chimney or flue	0.0%	0.0%	0.1%	0.0%
117	Commercial Compactor fire, confined to rubbish	0.1%	0.0%	0.1%	0.1%
118	Trash or rubbish fire, contained	1.8%	0.4%	1.4%	1.4%
120	Fire in mobile property used as a fixed structure, other	0.2%	0.3%	0.4%	0.3%
121	Fire in mobile home used as fixed residence	0.4%	1.5%	2.6%	1.2%
122	Fire in motor home, camper, recreational vehicle	0.9%	1.2%	1.4%	1.1%
123	Fire in portable building, fixed location	0.5%	0.1%	0.5%	0.4%
130	Mobile property (vehicle) fire, other	2.8%	1.2%	3.7%	2.6%
131	Passenger vehicle fire	31.1%	23.5%	27.9%	28.6%
132	Road freight or transport vehicle fire	0.9%	1.5%	4.6%	2.0%
134	Water vehicle fire	0.2%	0.6%	1.0%	0.5%
135	Aircraft fire	0.0%	0.0%	0.1%	0.0%
136	Self-propelled motor home or recreational vehicle	0.1%	0.4%	0.5%	0.3%
137	Camper or recreational vehicle (RV) fire	0.4%	2.1%	2.3%	1.2%
138	Off-road vehicle or heavy equipment fire	0.2%	0.4%	1.6%	0.6%
140	Natural vegetation fire, other	1.2%	2.2%	1.0%	1.4%
141	Forest, woods or wildland fire	0.1%	0.4%	0.5%	0.3%
142	Brush or brush-and-grass mixture fire	0.7%	5.4%	4.9%	2.8%
143	Grass fire	2.2%	6.5%	6.8%	4.3%
150	Outside rubbish fire, other	1.7%	0.3%	0.4%	1.1%
151	Outside rubbish, trash or waste fire	4.0%	1.5%	1.9%	2.9%
154	Dumpster or other outside trash receptacle fire	1.8%	1.3%	1.4%	1.6%
155	Outside stationary compactor/compacted trash fire	0.1%	0.0%	0.0%	0.0%
160	Special outside fire, other	2.2%	3.2%	1.4%	2.3%
161	Outside storage fire	2.1%	1.6%	1.5%	1.9%
162	Outside equipment fire	0.9%	0.7%	0.4%	0.8%
163	Outside gas or vapor combustion explosion	0.0%	0.0%	0.3%	0.1%
170	Cultivated vegetation, crop fire, other	0.1%	0.1%	0.3%	0.1%
171	Cultivated grain or crop fire	0.1%	0.0%	0.4%	0.1%
172	Cultivated orchard or vineyard fire	0.1%	0.0%	0.4%	0.1%
173	Cultivated trees or nursery stock fire	0.4%	0.1%	0.1%	0.3%
100	Other fire	5.2%	7.1%	1.8%	4.8%
Grand total		100.0%	100.0%	100.0%	100.0%

This report is submitted to the U.S. Fire Administration National Fire Data Center by PG Public Services, LLC in accordance with the Performance Work Statement under contract 70FA2019P00000035.